The Full-sky Astrometric Mapping Explorer

Lessons Learned
Presented to
Explorer Retreat
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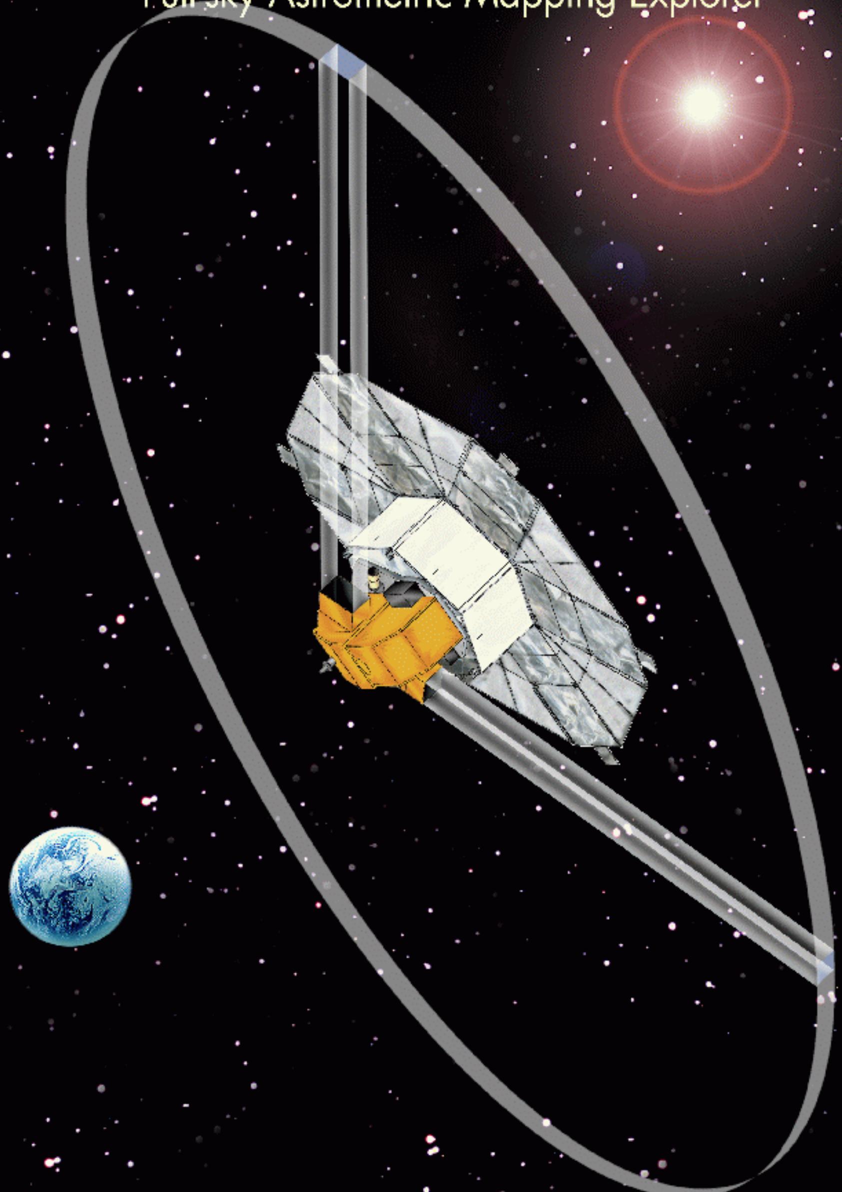
Kenneth J. Johnston
Scientific Director
U.S. Naval Observatory

FAME

Full-sky Astrometric Mapping Explorer



Full-sky

Astrometric

Mapping

Explorer

http://www.usno.navy.mil/fame

Full-sky Astrometric Mapping Explorer

United States Naval Observatory

PI, Oversight of science and budget, MO&DA Lead, GDS, MOC, & SOC development and implementation, E/PO Lead

Naval Research Laboratory

PM, System Engineering, S/C bus development, integration, & test, Comprehensive testing

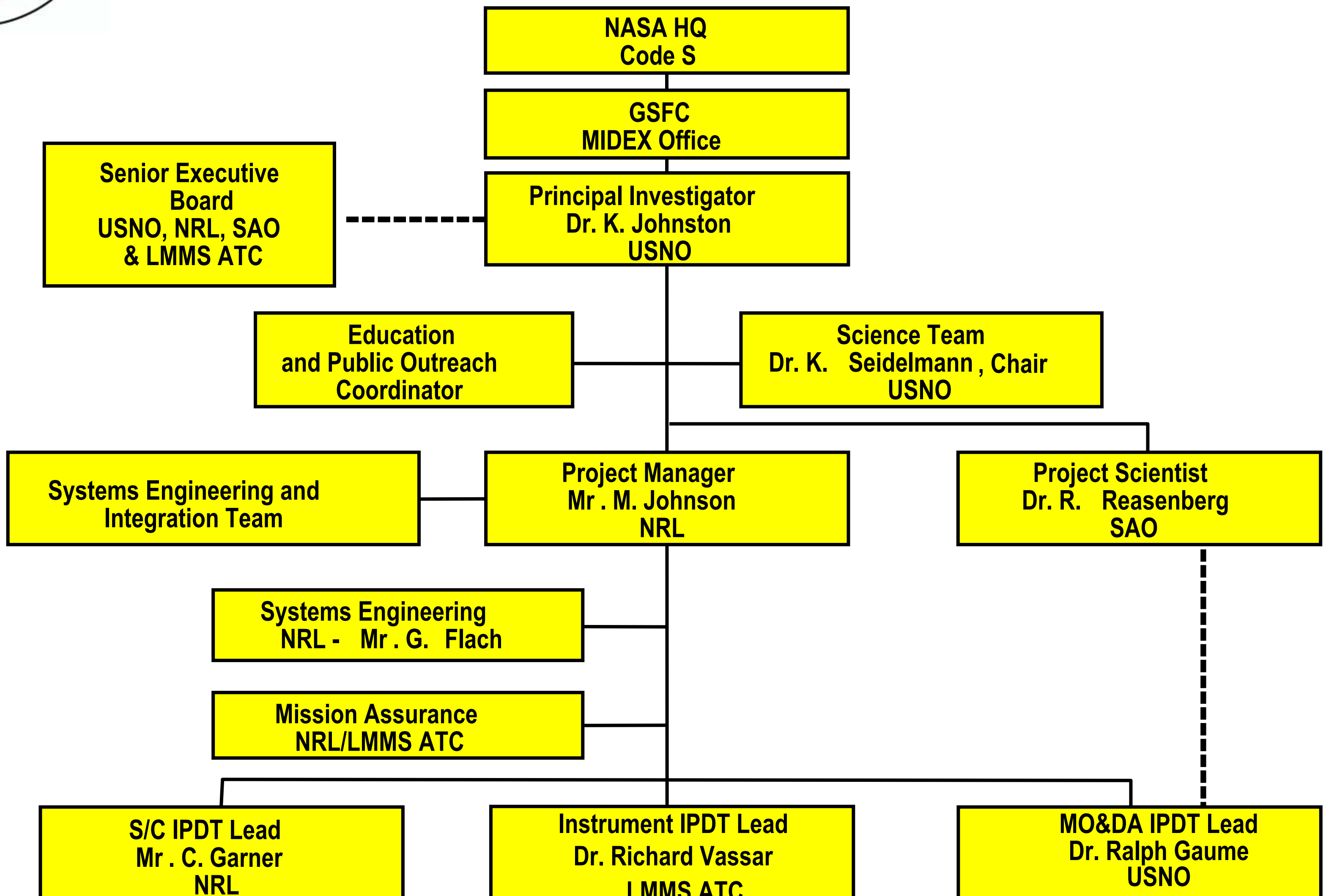
Lockheed Martin Missiles and Space

Instrument design, fabrication, testing, & support

Smithsonian Astrophysical Observatory

PS, Synthesis and verification of scientific measurement system, E/PO support

FAME Management

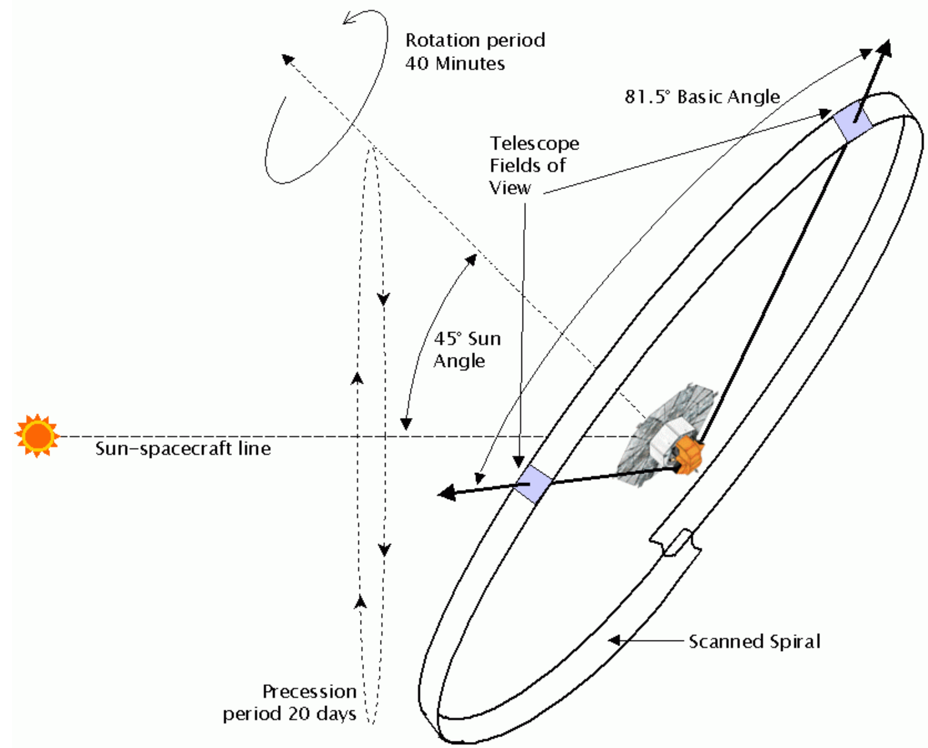


Technical Goals and Objectives of FAME

- **FAME will perform an all sky, astrometric survey with unprecedented accuracy**
  - **Upgrades existing star catalogs by providing a precision catalog of 4×10^7 Stars**
  - **Provides positions of bright stars ($5<m_v<9$) to $<50\mu as$**
  - **Provides positions of fainter stars ($9<m_v<15$) to $<500\mu as$**
  - **5 year extended mission allows for accurate measurement of stellar parallax, proper motions, and monitoring of stellar variability**
  - **Photometric data in four Sloan DSS bands (g', r', i', z')**

FAME Mission Description

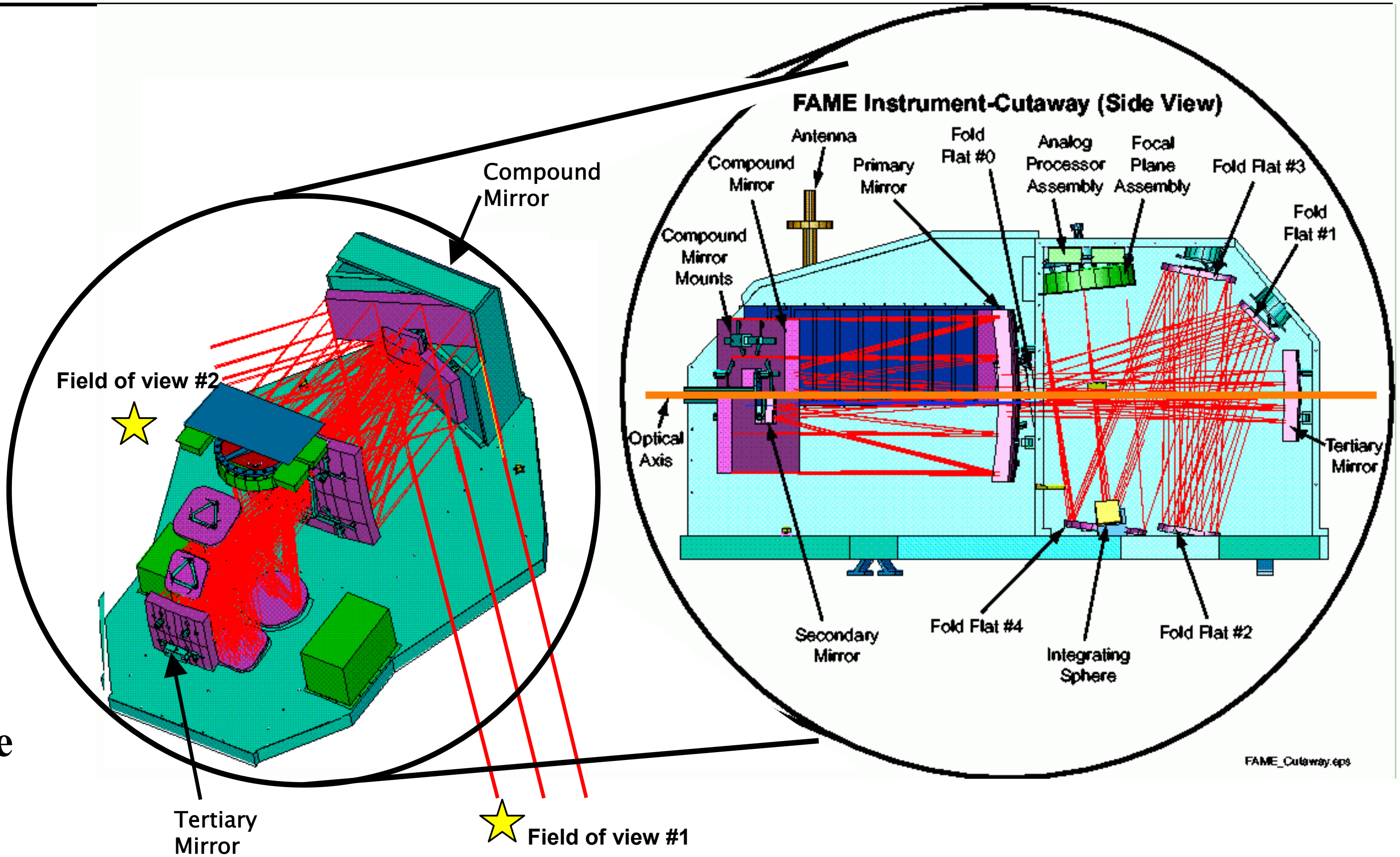
- The telescope has two fields-of-view separated by a 81.5° basic angle
- The spacecraft will rotate with a 40 minute period with the apertures sweeping out a great circle on the sky
- The spacecraft rotation axis is at a 45° angle to the Sun
- The solar radiation pressure on the solar shield results in precession about the Sun-spacecraft line with a 20 day period
- The spacecraft is in Geosychronous orbit for continuous contact



The FAME observing concept - The axis of the FAME spacecraft is pointed 45° from the Sun and precesses around the Sun with a 20 day period. The FAME spacecraft rotates with a 40 minute period. The two fields of view are normal to the rotation axis and are separated by a 81.5° degree basic angle.

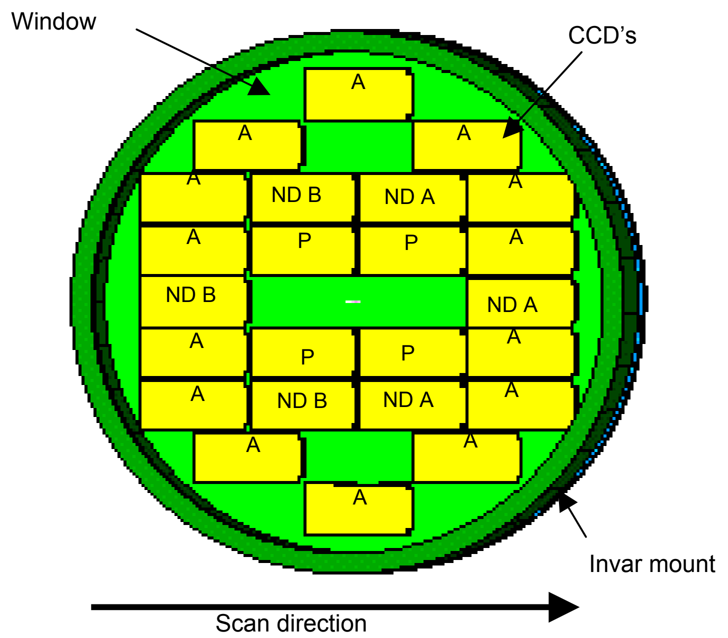
FAME Instrument Description

- Two input apertures
- 60 × 25 cm aperture size (each)
- Total mass 229 kg
- Total power 272 W
- 400 to 900nm spectral range
- Back illuminated CCDs



- Instrument developed by Lockheed Martin Missiles and Space ATC

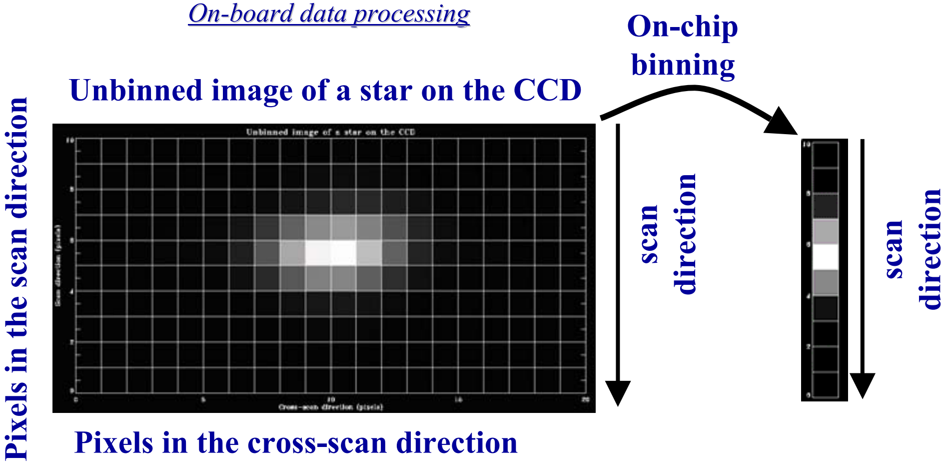
FAME Instrument Description



The FAME focal plane - 24 2k·4k CCDs arranged around a 1.1° diameter field of view. Devices marked with 'P' are the 4 photometric CCDs and devices marked with 'A' are the 20 astrometric CCDs. The 6 devices marked with 'ND' have neutral density filters for astrometry of brighter stars.

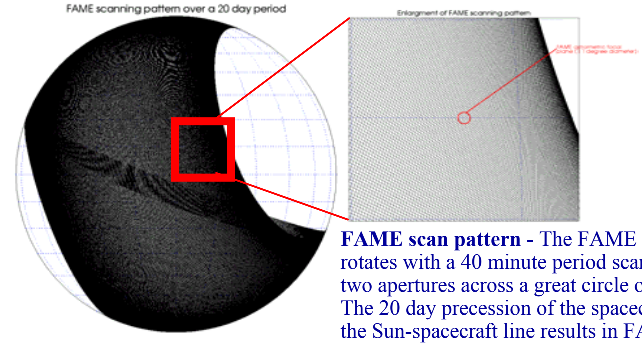
- **Telescope produces images of Stars using 24 large format CCDs**
  - **Images of stars are continually traversing CCD array as the spacecraft rotates**
  - **CCDs use time delay integration**
  - **Synchronization of CCD clock rate and image motion is assured via rotation rate sensors**
  - **Star images are time tagged, windowed, and transmitted to Earth.**
  - **6 CCDs are covered by neutral density filters for astrometry of bright stars**

On-board data processing



- The data from most stars are binned by 20 in the cross-scan direction on the CCD before being read-out

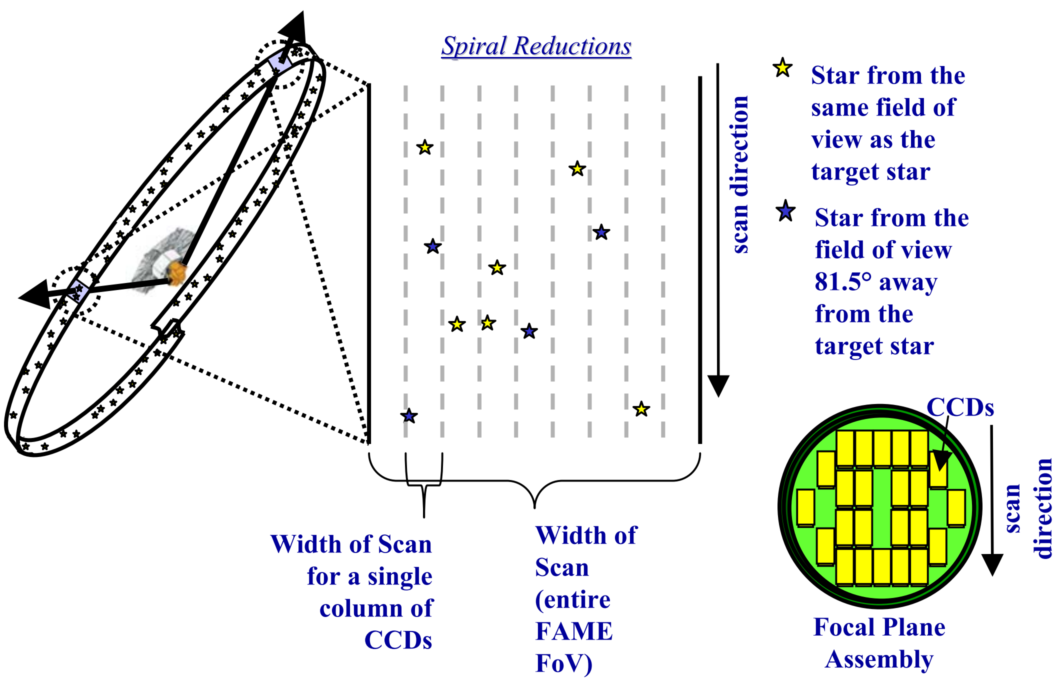
Sphere Reconstruction



FAME scan pattern - The FAME spacecraft rotates with a 40 minute period scanning the two apertures across a great circle on the sky. The 20 day precession of the spacecraft about the Sun-spacecraft line results in FAME covering the entire sky except for exclusion zones within 45° of the Sun and the anti-Sun direction every 20 days.

- Use a subset of the stars to globally tie the spirals together into a sphere

Spiral Reductions



Original FAME Schedule

Phase A Concept Study
February - June 1999

Phase B
September 2000 - June 2001

Phase C
July 2001 - March 2002

Phase D
April 2002 - June 2004

Launch
June 2004

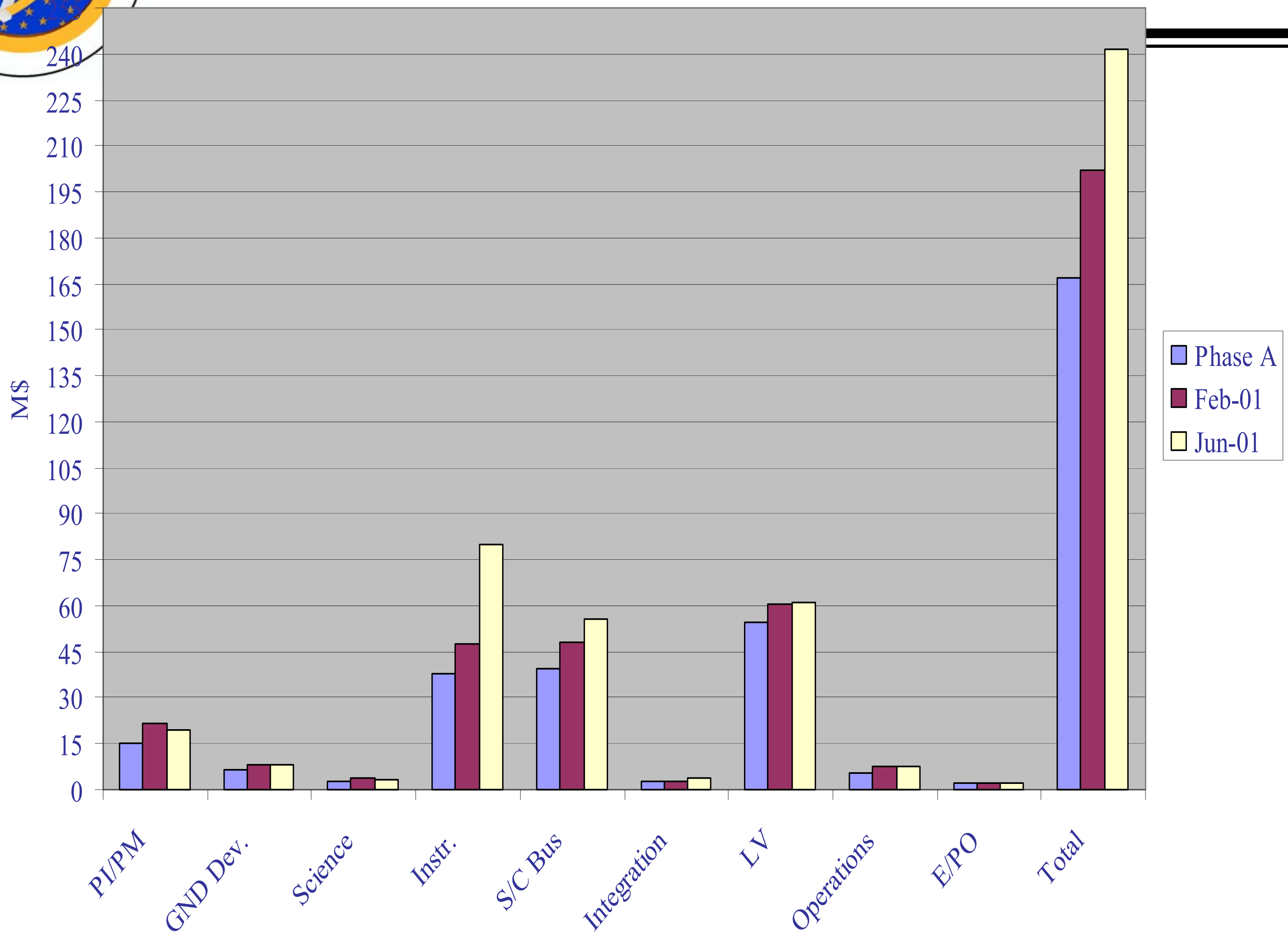
Phase E
July 2004 - January 2008

DoD Extended Mission
January 2007 - July 2010

Major Milestones in Phase B

- Define Requirements
- Delivery of CCDs
  - March 2001 Two Evaluation CCDs
  - June 01 10 Engineering Model CCDs
  - December 2001 44 Flight CCDs
- Optics
  - Optics Contract in Place January 10, 2001
  - Optical Elements Delivered July 7, 2002
- Bus
  - Procure Long Lead Items

FAME Cost Estimates June 01
Real Year $



Budget June 01

- Cost Increases
  - Program Delay
    - 4 month slip
  - Optical Design
    - Increase in fabrication costs
      - Schedule slip 10 - 22 months
    - focus
  - CCD's
    - Delay in fabrication
    - power consumption
      - mass increase
  - ACS/Solar Precession
    - Mass increase
  - Overhead Costs

Efforts to Reduce Cost

- Re-Scope Mission with Minimal Impact to Science
  - Reduce area of optics by 50%
    - Reduces Mass/Simplified Fabrication
  - Reduce Number of CCDs to 13
    - Reduction in Power and Data Rate
- Pull schedule back in 8 months (to Oct 04 launch date)
  - Optics Lead time drives overall schedule
- Simplify Spacecraft Bus
  - Reduce Sun Angle to 35 degrees
    - Eliminate Deployable Arrays
  - Reduce Data Rate by 50%
    - Half the CCDs – Eliminate Power Amplifiers

FAME Schedule

- Aug 2001
  - Re-scope Instrument/Bus
- Sept 2001
  - Science Team Input
- Nov 2001
  - PDR
- Dec 2001
  - Confirmation Review
- Recover Original Schedule

Independent Confirmation Assessment Team (ICAT)

- Science: Still Very Attractive
- Management & System Engineering
  - C/D Baseline is appropriate
- Spacecraft
  - Schedule/Cost Risk is LOW to MEDIUM
- Instrument
  - Overall Risk HIGH, Primarily due to Tight Schedule
- MO&DA
  - Technical Risk is LOW to MEDIUM
- Schedule
  - Program Schedule Risk is HIGH

ICAT Instrument Comments

- Design Maturity
  - Very Low due to Major Redesign
- No Slack in Development Schedule
  - CCD Yield Low to Date
  - Optical Design Incomplete
- Cost
  - Has grown significantly & will grow more

January 2001

- Cancellation of FAME Mission
  - Uncertainty surrounding the development of instrument CCDs and optics, instrument software development and operations algorithm development
    - » And
  - Significant mission cost growth that exceeds the cost cap by more than $40 million and the uncertainty additional resources needed to successfully complete the mission

Lessons Learned

- Phase A Plans
- Phase A Cost/Schedule Estimates
  - Optimistic Costs/Schedule
  - Difficulty Meeting Original Cost Cap of 140M(98$)
- Planned Inadequate Budget Reserves
  - 10% bus, 20% instrument in Phase C/D
  - 30% reserve on entire project would have been reasonable

Lessons Learned

Phase B

Communications

- Project scientist
  - Delay in replacement
- LMATC-USNO Scientists
  - Critical requirements for optics

- Loss of Key Personnel
- Science Req => Engineering Req
- Project Management Office
  - Staffing: Program Office, Systems Engineering

Lessons Learned

- Developing New Technologies
  - CCDs
    - Readout rate >3Mhz
    - Charge Injection for radiation mitigation
  - Spin Dynamics of Observatory
    - Impossible to demonstrate on the ground

Recommendations

- Allow Adequate Reserves
- Need Realistic Estimate of Costs/Schedule
- Reduce Risks on Unique Items
  - Alternate CCD order
- Must have Integrated Science/Engineering Team
- Need Viable Descope Options
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